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ESTIMATION OF ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS FROM FERTILIZER USE IN CORN, COTTON AND SOYBEAN PRODUCTION IN TURKEY

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Abstract

This study investigates the energy consumption and greenhouse gas emissions from fertilizer use for corn, cotton and soybean production in Turkey. For corn and cotton cultivation 403.33 kg NPK is applied before planting per hectare, 238.33 kg AN and 238.33 kg urea after planting. For soybean production 201.66 kg DAP before planting per hectare, 135.83 kg AN and 135.83 kg urea after planting are applied. For corn cultivation, 11,991.65 MJ fertilizer energy is consumed per hectare in Turkey. However 8973.56 MJ and 6,452.94 MJ fertilizer energy is consumed per hectares in cotton and soybean production, respectively. The total GHG emissions from fertilizer application are 2,603.7 kg CO_2-eq, 1,949.13 kg CO_2-eq and 1,523.22 kg CO_2-eq per hectares, respectively.

Key words: *corn, cotton, soybean, fertilizer, energy, emission*

INTRODUCTION

In order to increase agricultural production, soil should be cultivated, planted, irrigated and diseases and pests should be fought. Along with all these processes, measures should be taken to increase plant nutrition and production. Plants, like humans and animals, have to feed for their growth. Plants take a large part of their nutrients from the soil with their roots. If there is not enough nutrients in the soil to meet the needs of the grown plants, plant nutrients should be given to the soil. If nutrients are not supplied to the soil, production decreases after a while due to the lack of nutrients. The plant needs to be fed in order to get sufficient and quality products. In plant production, organic and inorganic sources are used to achieve the intended yield and quality.

In order to achieve the intended yield and quality in plant production, fertilization is the application of organic or inorganic compounds containing one or more plant nutrients to the soil or directly to the plant. Fertilization has two main purposes:

1)Enriching the soil with plant nutrients

2)Improving the physical and biological properties of soils, providing a better development environment for the plant to be grown.

Due to the fact that it is no longer possible to increase agricultural areas and the diversification of the needs of the population increases, it is necessary to take effective and widespread measures to ensure that more products are taken from the unit area. In order to meet the food needs of the world's population, it requires the use of more inputs to obtain more efficiency from the unit area. In all branches of agriculture, high quality seed, mechanization, plant breeding, as well as effective protection measures, irrigation and rainfall-dependent fertilization is necessary. Vegetable products increased with fertilizer application also form the basis of livestock and agriculture-based industry. According to the researches, the effect of fertilizer on the amount of product to be obtained in agricultural inputs is determined as 50-60% in developing countries. Fertilizers, which have a share of 10-15% in agricultural product costs, can increase their product yields by more than 50% alone. Therefore, as the nutrients present in the soil do not always meet the needs of the plant, agricultural soils should be enriched with the missing nutrients (Ozturk, 2010) [4].

This study investigates the energy consumption and greenhouse gas emissions from fertilizer use for corn, cotton and soybean production in Turkey.

Energy consumption in chemical fertilizer production

Fertilizer production is an energy intensive sector. Approximately 15% of the total energy consumed in the industrial sector is consumed in the fertilizer production sector (Gielen, 2006) [1]. Different energy sources, mainly hydrocarbons, are used for fertilizer production, fuel and nitrogen are used for ammonia production. Intermediate products are used in compound fertilizer production (Mudahar and Hignett, 1987) [3].

Energy consumption in chemical fertilizer production is examined in two ways as specific energy consumption and total energy consumption. Specific energy consumption is defined as the amount of energy used from fuel, heat, electrical or mechanical energy types to produce a unit of product (fertilizer) (Ramirez and Worrell, 2006) [5].

Total energy consumption is defined as the amount of energy for all processes, including the amount of energy consumed to produce raw materials in a given production process. Total energy consumption can also be defined as a simple life cycle analysis focused on energy use in fertilizer production. For example, specific energy consumption for ammonium nitrate is the amount of heat, fuel and electricity used to produce 1 ton of ammonium nitrate from ammonium and nitric acid, while total energy consumption includes amounts of energy from the types of electricity, heat and fuel used to produce ammonium and nitric acid (Ramirez and Worrell, 2006) [5].

The energy equivalent of chemical fertilizers used in agricultural production is calculated from the energy equivalents of all inputs used in fertilizer production processes. In other words, the energy costs of chemical fertilizers are directly related to the techniques used in the production of these fertilizers. Due to technological developments, the amount of energy used in the production of chemical fertilizers has decreased significantly in recent years.

Greenhouse gas emissions in chemical fertilizer production

The increase in greenhouse gas emissions in the atmosphere increases the importance of CO_2, N_2O and CH_4 emissions released by agricultural practices. These gases are released either directly during agricultural operations or indirectly during the production and transport of necessary inputs such as pesticides and chemical fertilizers. Too much energy is consumed in the production of chemical fertilizers. Therefore, too much greenhouse gas (GHG) emissions occur. Approximately 1.2% of the world's energy consumption is used for chemical fertilizer production. Therefore, approximately 1.2% of the total GHG emissions occur as a result of chemical fertilizer production. Release factors are an important tool for the life cycle analysis of agricultural production systems (Wood ve Cowie, 2004) [6].

During the life cycle of chemical fertilizers, GHG emissions may be released during the extraction, transport and processing of raw materials. Emissions from fertilizer application to the field are not considered here. Significant GHG emissions from fertilizer production are CO_2, N_2O and CH_4. Emission factors are expressed as CO_2 equivalent (g CO_2-e/kg fertilizer) per unit mass of fertilizer.

Ammonia (NH_3) is the primary input for a significant proportion of nitrogenous fertilizer production in the world. In GHG emissions for nitrogenous fertilizer production, N_2O emissions resulting from the production of CO_2 and nitric acid from ammonia production play an important role. Ammonia synthesis is a process with high energy consumption. Today, in the steam configuration process for fertilizer production, approximately 25-35 GJ of energy is consumed per tonne of ammonia produced. The main energy source for ammonia synthesis is natural gas. The CO_2 produced by the consumption of natural gas or other hydrocarbons to meet the energy requirements of the process is the most important greenhouse gas produced by ammonia production (Wood ve Cowie, 2004) [6].

Urea constitutes approximately half of the nitrogenous fertilizer production in the world. Urea synthesis is based on the principle of combining ammonia and carbon dioxide at high pressure to form ammonium carbonate. As a result of urea production, CO_2 is released during ammonia synthesis (Wood ve Cowie, 2004) [6].

The main greenhouse gas released by phosphorus fertilizer production is CO_2. CO_2 is released as a result of consuming fossil fuels as an energy source for various production processes related to the production of phosphorus fertilizers. The net emission values from phosphorus fertilizer production can be determined depending on the sulphuric acid production method.

MATERIALS AND METHODS

The main characteristics of the fertilizers used in corn, cotton and soybean production in Turkey are given in Table 1.

Table 1. Application Rate and Times of Fertilizers for Crops in Turkey

Fertilizers	Chemical Contents (%)
Ammonium nitrate (AN)	33.5 N
Ammonium phosphates (DAP)	18 N, 46 P_2O_5
NPK 15-15-15	15N-15P_2O_5-15K_2O
Urea	46 N

Source: Own research results.

The application rate and times of fertilizers for crops in Turkey are given in Table 2-4.

Table 2. The Application Rate And Times Of Fertilizers For Corn

Crop	Corn	
Application time	**Before sowing**	**After sowing**
Fertilizers	**Application rate (kg/ha)**	
Ammonium nitrate		238.33
NPK 15-15-15	403.33	
Urea		238.33

Source: Own research results.

Table 3. The Application Rate And Times Of Fertilizers For Cotton

Crop	Cotton	
Application time	**Before sowing**	**After sowing**
Fertilizers	**Application rate (kg/ha)**	
Ammonium nitrate		181.25
NPK 15-15-15	287.5	
Urea		181.25

Source: Own research results.

Table 4. The Application Rate And Times Of Fertilizers For Soybean

Crop	Soybean	
Application time	**Before sowing**	**After sowing**
Fertilizers	**Application rate (kg/ha)**	
Ammonium nitrate		135.83
Ammonium phosphates	201.66	
Urea		135.83

Source: Own research results.

In corn and cotton production 403.33 kg NPK is applied before planting per hectare, 238.33 kg AN and 238.33 kg urea after planting. In soybean production 201.66 kg DAP before planting per hectare, 135.83 kg AN and 135.83 kg urea after planting are applied.

Energy input of fertilizer consumption

The amount of energy consumed related to fertilizer using in unit production area (ha) for crop cultivation is calculated depending on the application rate of fertilizer used and energy consumption per kg product for fertilizer production on site, as it can be seen down below:

$$E_f = M_f \times PE_f \quad \text{.........................}(1)$$

where:
E_f = Fertilizer energy consumption (MJ/ha),
$\boldsymbol{M_f}$ = Application rate of fertilizer (kg/ha) and
PE_f = Production energy of fertilizer (MJ/kg).

Calculation methodology used for carbon dioxide emissions

The following equation outlines the recommended approach to calculating total GHG emissions based on fertilizer use.

$$GHG = M_f \times ECE_f \quad \text{.......................}(2)$$

where:
GHG = Total CO_2-eq emission per area (kgCO_2-eq/ha),
$\boldsymbol{M_f}$ = Application rate of fertilizer (kg/ha) and
ECE_f = Total CO_2-eq emission per kg product for production and application of fertilizer (kg CO_2-eq/kg) (Table 5).

Table 5. The Application Rate And Times Of Fertilizers For Soybean

Fertilizers	Energy consumption for production on site (MJ/kg)
Ammonium nitrate (AN)	14.02
Ammonium phosphates (DAP)	6.76
NPK 15-15-15	7.59
Urea	23.45

Source: IPCC, 2006 [2].

RESULTS AND DISCUSSIONS

Energy consumptions for fertilizer production

The energy consumptions for fertilizer production are given in Figure 1. The approximately 23.45 MJ energy per product is consumed for production of urea on site. On the other hand, 14.02 MJ energy is consumed for production of AN. For the production processes of NPK and AN fertilizers in factories, 7.59 MJ and 6.76 kg energy are consumed per kg product, respectively.

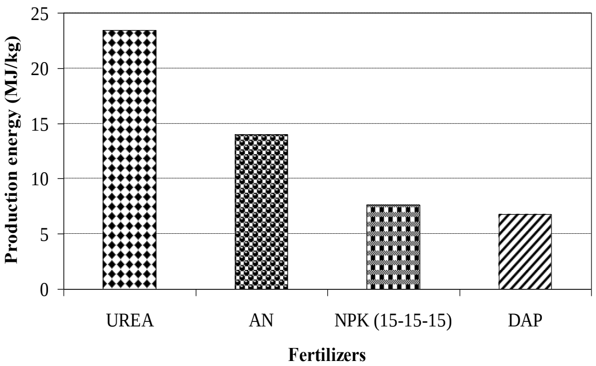

Fig. 1. The Energy Consumptions For Fertilizer Production
Source: Own research results.

Fertilizer applications for crops

The fertilizer applications for crops are given in Figure 2.

For corn and cotton cultivation 403.33 kg NPK is applied before planting per hectare, 238.33 kg AN and 238.33 kg urea after planting. For soybean production 201.66 kg DAP before planting per hectare, 135.83 kg AN and 135.83 kg urea after planting are applied.

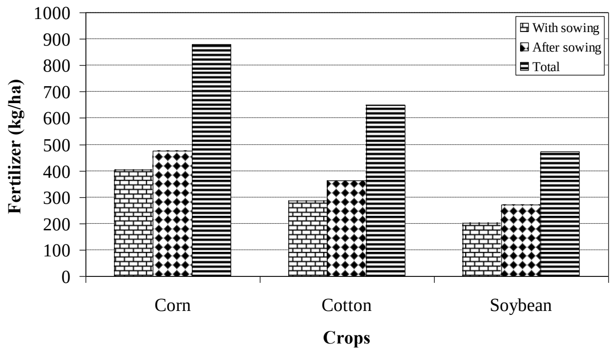

Fig. 2. Fertilizer Applications For Crops
Source: Own research results.

Fertilizer energy consumptions for crops

The fertilizer energy consumptions for crops are given in Figure 3. For corn cultivation, 11,991.65 MJ fertilizer energy is consumed per hectare in Turkey. However 8,973.56 MJ and 6,452.94 MJ fertilizer energy is consumed per hectares in cotton and soybean production, respectively.

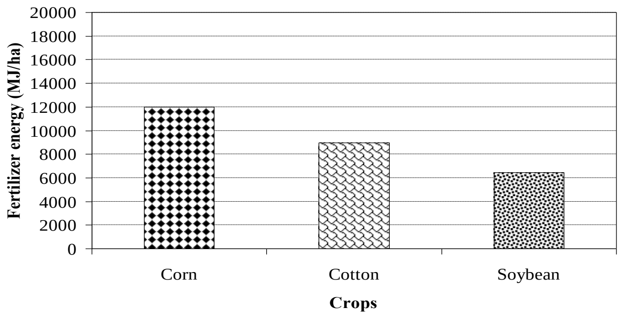

Fig. 3. Fertilizer Energy Consumptions For Crops
Source: Own research results.

GHG emissions from fertilizer production and application

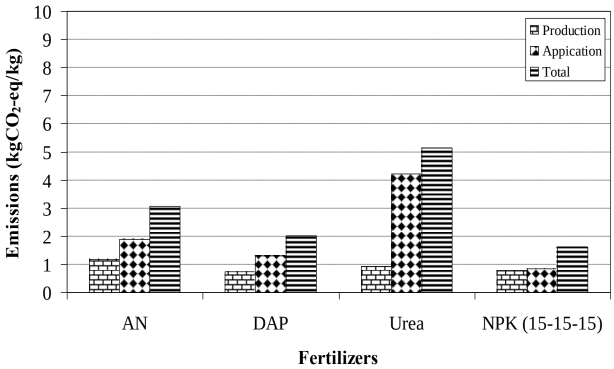

Fig. 4. GHG Emissions For Production And Application Of Fertilizers
Source: Own research results.

Figure 4 gives the levels of GHG emissions per kg product from fertilizer production and application depending on the fertilizer types. The GHG emissions from production of AN fertilizer in factory and field application are 1.18 kgCO_2-eq and 1.89 kgCO_2-eq per kg product, respectively. Therefore, the total GHG emission from AN utilization is 3.07 kgCO_2-eq per kg product.

Application of 1 kg urea and DAP fertilizers to the field cause 4.22 kgCO_2-eq and 1.3 kgCO_2-eq emissions, respectively. When these values are added to the GHG emissions from the production of these fertilizers, a total of 5.13 kgCO_2-eq and 2.03 kgCO_2-eq of emissions are generated, respectively. The GHG emissions from production of NPK (15-15-15) fertilizer in factory and field application are 0.76 kgCO_2-eq and 0.85 kgCO_2-eq per kg product, respectively. Therefore, the total GHG emission from NPK (15-15-15) utilization is 1.61 kgCO_2-eq per kg product.

Figure 5 gives the levels of GHG emissions per kg hectare from fertilizer application for crop cultivations. The total GHG emissions from fertilizer application are 2,603.7 kg CO_2-eq, 1,949.13 kg CO_2-eq and 1,523.22 kg CO_2-eq per hectares for corn, cotton and soybean cultivation, respectively.

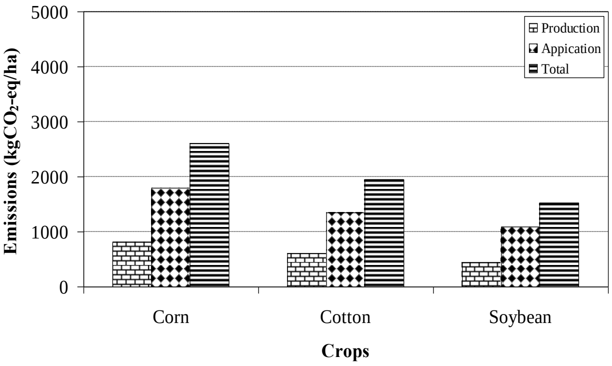

Fig. 5. GHG Emissions For Application Of Fertilizers
Source: Own research results.

CONCLUSIONS

For corn cultivation, cotton and soybean cultivation in Turkey, 11,991.65 MJ, 8,973.56 MJ and 6,452.94 MJ of fertilizer energy is consumed per hectare.

In Turkey, the total GHG emissions from fertilizer application are 2,603.7 kg CO_2-eq, 1,949.13 kg CO_2-eq and 1,523.22 kg CO_2-eq per hectares for corn, cotton and soybean cultivation, respectively.

Improvement in energy efficiency is the main target of developments in fertilizer production technology. The responsible production and use of mineral fertilizers in agriculture should be considered not only as an essential part of the global production of food, but also as part of the solution to climate change problems. Because growers cannot influence the climatic conditions under which they operate, efforts should be focused towards maintaining a good soil structure that enables good drainage and avoids water logging. The choice of the right N fertilizer product under the given conditions (e.g. nitrate-based products applied on non-waterlogged soils) can help minimize N_2O emissions from the soil.

Energy efficiency measures can be applied at all stages along the agrifood chain. Energy efficiency improvements can bring direct savings through technological or behavioural changes, or indirect savings through co-benefits derived from the adoption of agroecological farming practices. For both large and small systems, any means of avoiding food wastage should be encouraged and can result in considerable savings in the energy, land and water used to produce this food that no one consumes. Knowledge-based precision farming provides reliable and flexible fertilizer applications.

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